Radiation Detection and Nuclear Materials Equipment to Enhance Education and Research in Nuclear and Radiological Engineering at the Georgia Institute of Technology

Final Report

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The Nuclear and Radiological Engineering (NRE) program at The Georgia Institute of Technology upgraded and enhanced its academic and research activities with the purchase and installation of equipment and instrumentation in four separate areas. The four areas addressed were:

1. Crystal growth furnace for nuclear and radiation detector materials applications
2. Addition of an associated particle system to existing neutron generator
3. Implementation of two liquid scintillation systems for neutron detection
4. Addition of instruments in the radiation detection laboratory including CZT detectors

1.) Crystal growth furnace for nuclear and radiation detector materials applications

To enhance the materials research capabilities in NRE program a Centorr Series 5TA, tri-arc furnace along with a Centorr Series 3, compact crystal puller were purchased and installed. The installation and commissioning of the furnace and crystal puller was assisted by two undergraduate students in the NRE program who received course credit for their work on the project.

One future application of the furnace will be to investigate the direct melt and casting of metal and ceramic forms of uranium. Both the Czochralski method and Bridgman method can be used to produce boules and crystals of uranium alloys, uranium oxide and nitrides. These single crystal boules can then be processed by using a diamond saw to produce pellets, wafers or substrate materials in the exact size configuration that is desired for experimental purposes. In order to study phase transformations as well as non-stoichiometry issues, we already have a simultaneous thermal analysis unit.

Another potential application of the furnace will be to grow single crystals of structural materials for nuclear reactors. Since there is complete control on composition, ideal alloys (Fe-Cr, Fe-Cu, Mo-Re etc) can be grown. These single crystals can then be considered for insertion in the Advanced Test Reactor in order to perform fundamental irradiation studies on structural materials for advanced nuclear systems.

The furnace will also be used to grow single crystals of scintillator materials for radiation detector development. Both gamma and neutron detector scintillator materials can be grown. In detection applications, it is essential that these materials be in single crystal form (with some exceptions) as interfaces and grain boundaries are sources of internal reflection of light. The NRE program has extensive facilities to test these scintillator materials with several reference neutron fields.

The furnace was chosen for its versatility and its ability to aid in science based research and development of materials for nuclear energy and radiation detection. In combination with other materials science capabilities within the Mechanical Engineering program of the Woodruff School and the Schools of Materials Science and Engineering, and Electrical and Computer Engineering, this equipment enhanced the research capabilities in nuclear and radiation detection materials across the Georgia Tech campus.

2.) Associated particle system for existing neutron generator

The NRE program purchased the necessary components for an associated particle system to be installed on an existing model 9440 Texas Nuclear neutron generator. The components purchased included silicon barrier alpha detectors, and associated electronics (power supply, pre-amplifier, amplifer, scaler, NIM bin and spectroscopy software. The purchased system was to be installed on the existing generator after a specifically designed shielding vault was completed in December 2011. Commissioning of the generator was attempted, but due to age of the machine a suitable vacuum for its operation was no longer possible. The components that were purchased for the associated particle system were similar or identical to components already used in the radiation detection laboratory class in the NRE program and have since been used in that lab for the previous two semesters as part of the components for one or more of the laboratory stations. In spring 2012, 14 graduate students were in the lab class and in fall 2012, a total of 69 undergraduate students were enrolled in the class

3.) Liquid scintillation systems for neutron detection

The NRE program purchased 3 NE-213 based liquid scintillation detectors along with 2-Mesytec MPD-4: particle discriminator modules for liquid scintillators and associated electronics (VME crate, photomultiplier tubes and bases, mu-metal shields, light pipes, power supplies, pre-amplifies, research amplifiers, time-amplitude converters, linear gates, and delays). These detectors will add to a wide array of neutron measurement instruments and capabilities that have been assembled at Georgia Tech. Existing neutron measurement facilities include the radiation detection laboratory and reference neutron fields for instrument and measurement technique development. Chief among the reference neutron source capabilities is a ^{252}Cf spontaneous fission neutron source (ISO 8529 reference field). Besides being used in its bare configuration to provide a fission spectrum, it can be placed in several moderating spherical shells to produce other reference fields: a 30-cm diameter, cadmium-covered D2O spherical shell (ISO 8529 reference field); a 30-cm thick iron spherical shell, a 30-cm diameter polyethylene sphere, an 18.3-cm thick tungsten spherical shell, a 16-cm thick lead spherical shell, and a 9-cm thick tantalum spherical shell.

Complementing this set of ^{252}Cf-based reference fields is a 54-Ci AmBe neutron source (ISO 8529 reference field) which produces a substantial number of (α,n) neutrons up to 12 MeV. The AmBe source can be inserted into the iron, tantalum, tungsten, and polyethylene shells previously described above. Additionally a small sealed tube pulsed neutron generator utilizing the D-T reaction to produce 14-MeV neutrons can be used in air and within the 30-cm thick iron spherical shell. Instruments currently available include a Tissue-Equivalent Proportional Counters for microdosimetry measurement, Dual Ion Chambers for mixed neutron and gamma field measurements, 1”, 2” 3” and 5” gas filled proton recoil neutron spectrometers, two Bonner Sphere (moderating) spectrometers, and a large inventory of thermal and threshold activation foils for use in neutron spectrum determination by foil unfolding.

Currently a graduate student is finishing up their master’s thesis on the implementation and characterization of these detector systems and electronics. Once completed, these detectors provided neutron detection capabilities with much higher resolution, after unfolding the pulse height spectra, than can be obtained with our Bonner Sphere spectrometers. In the future these detectors with the gas-filled proton recoil detectors will allow measurements to be performed of an extended range of neutron energies (10’s keV - 40-50 MeV). These detectors are will enhance the NRE programs neutron spectroscopy capabilities for homeland security, for neutron benchmark experiments in support of data needs for the next generation of reactors, and for other general experiments like the measurement of neutron fields around filled dry storage canisters.

4.) Instrumentation upgrades to equipment in the GT radiation detection laboratory

The NRE program purchased 7 Co-planar grid CdZnTe (CZT) detectors (one for each laboratory station) and has implemented them into the undergraduate and graduate radiation detection courses. In this lab students investigate and learn about the properties of CZT detectors (resolution, efficiency, etc) in comparison with the existing NaI and HPGe detectors.